GUIDELINES FOR THE PROTECTION OF STEEL PILES

Corrosive Marine Environment

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Bachelor's Thesis

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Graham Andrew Rhodes

HAMK
UNIVERSITY OF APPLIED SCIENCES

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Author	Graham Andrew Rhodes
Supervised by	Lassi Martikainen
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ABSTRACT

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ABSTRACT

The corrosion of steel is a common phenomenon. In a marine environment, steel is corroded at an accelerated rate due to the atmospheric conditions. To combat this corrosion, steel piles are coated in order to protect them. As a major supplier of steel piles, Rautaruukki Oyj (Ruukki) commissioned this project in order to streamline their coating process. Currently Ruukki supplies a different coating system for almost every job; the aim of the project was to reduce the number of systems used to less than five, and then to produce an easy to use sales tool to aid Ruukki's sales team. Key factors affecting the choice of paints included lead time, VOC content, substrate surface preparation and corrosion protection category.

Each protection system was required to be compatible with cathodic protection as this is common to almost all installations. All systems were required to adhere to the highest standards of protection according to ISO 12944-5, and had to be easily repairable if any transportation or installation damage should occur. One desirable feature of the coatings was the possibility of application in winter conditions; this was due to some uncertainty surrounding the location of the painting facility.

The result of the background research and meetings with both Ruukki's staff and the paint suppliers was the selection of three different paint systems, all with unique selling points and varied qualities. Each paint was supplied by a different company; Tikkurila Oyj, Nor-Maali Oy and Steelpaint GmbH, and each paint was made from a different base material; epoxy, polyester and polyurethane respectively.

Suggestions for the next stage of the project include: laboratory tests to validate the claims of the paint suppliers; a time-axis flow chart comparison of systems in order to identify any other logistical difficulties such as packing the piles for transport; and finally and most importantly, incorporating all of these ideas into a cost analysis. The cost analysis was impossible to complete in the scope of this project due to suppliers not wanting to negotiate price at this level of proceedings.

Keywords Steel piles, Corrosion, Coating, Painting.

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TIIVISTELMÄ

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Työn nimi: Ohjeet teräspaalujen suojaukseen syövyttävältä meri-ilmastolta

TIIVISTELMÄ

Meri-ilmastossa teräs syöpyy nopeasti ankarien ilmasto-olosuhteiden vuoksi. Korroosion estämiseksi teräspaalut tavallisesti suojataan maalipinnoitteilla. Merkittävä teräspaalujen tuottaja Rautaruukki Oyj (Ruukki) antoi tämän opinnäytetyön tehtäväksi järkeistäkseen teräspaalujensa pinnoitusprosessia. Nykyisin Ruukki toimittaa eri pinnoitejärjestelmän lähes jokaiseen hankkeeseensa. Opinnäytetyön tarkoituksena oli vähentää käytettävien pinnoitejärjestelmien määrä alle viiteen ja tuottaa Ruukin myyntitiimille helppokäyttöinen menetelmä pinnoitusmenetelmän valitsemiseksi. Avaintekijät pinnoitteiden valinnassa ovat läpimenoaika, haihtuvien orgaanisten yhdisteiden määrä (VOC), perusmateriaalin pintakäsittely ja korroosiorasitusluokka.

Kaikkien pinnoitejärjestelmien on sovelluttava katodiseen suojaukseen, koska sen käyttö on yleistä lähes kaikissa asennuksissa. Kaikilta järjestelmiltä vaaditaan korkeimman suojausluokan mukainen adheesio standardin ISO 12944-5 mukaisesti ja niiden on oltava helposti korjausmaalattavissa, sillä kuljetuksessa tai asennuksessa syntyy helposti vaurioita. Työmaalle sijoitetun maalauslaitoksen vaihtelevista ympäristöolosuhteiden vuoksi maalipinnoitteen on oltava levitettävissä talviolosuhteissa.

Taustaselvitystyön sekä Ruukin henkilökunnan ja maalintoimittajien kanssa käytyjen neuvottelujen lopputuloksena valittiin kolme erilaista maalijärjestelmää, joilla kaikilla olivat omat myyntivalttinsa. Kunkin maalin toimitti eri yritys: Tikkurila Oyj, Nor-Maali Oy ja Steelpaint GmbH. Jokainen maali perustui erilaiseen hartsityyppiin: epoksiin, polyesteriin ja polyuretaaniin.

Ehdotuksina jatkotutkimusaiheiksi ovat: laboratoriotestit maalintoimittajien antamien tietojen todentamiseksi, järjestelmien aikaperusteinen vuokaaviovertailu muiden logististen vaikeuksien havaitsemiseksi, sekä lopuksi tärkeimpänä toimenpiteenä kaikkien näiden ajatusten yhdistäminen kustannusanalyysissä. Kustannustarkasteluja ei voitu tehdä tässä opinnäytetyössä, koska maalintoimittajat eivät halunneet antaa tuotteidensa hintatietoja.

Avainsanat Teräspaalut, korroosio, pinnoite, maalaus.

Sivut 22 s. + liitteet 24 s.

CONTENTS

1 INTRODUCTION

Steel is used as a construction material in many ways. Industrial buildings, bridges and docks are just three examples of the type of structure in which steel is used. Steel can be used as a structural material above ground, or below ground or water in the form of piles.

Rautaruukki Oyj (Ruukki) based in Finland is a large international company that sells steel as a construction material in many forms. For the purpose of this thesis, the focus will be solely on steel piles. Many steel piles require some form of protective coating in order to endure the atmospheric conditions in which they will be installed.

In most invitations to tender, the resistance of the piles against corrosion or even the specific requirements for their coating is defined (usually by referring to related standards). The coating required is usually not the most beneficial for Ruukki when considering cost or lead time. Therefore it would be useful for the sales team at Ruukki to have information regarding the different coating systems and their equivalence to other coating systems used in Finland. This would help Ruukki to instruct the customer to use a coating that fulfils the same requirements, only more suitable for Ruukki.

The purpose of this thesis was to produce something, a flow chart or table for example, in order to aid the sales staff of Ruukki in recommending the best coating available for the steel piles being purchased. The aid should enable the sales staff to analyse the customers' various requirements from a protective coating and give them options to satisfy these requirements. These recommendations will be based on an analysis of the corrosivity category of the environment in which the piles will spend the duration of their life. Determining the best available protection will be achieved by cross-referencing what Ruukki's customers require with what is available at a reasonable cost.

In order to achieve this goal, a lot of background research is required. Considering Ruukki's customers and enquiring about the atmospheric conditions they require the coatings to withstand and for how long, contacting paint companies to see what paints are available to be used as coatings, and using ISO 12944 as a guideline for limit values.

There are many factors to consider when selecting a coating for steel elements; the thickness and the chemical compounds are the main considerations. The corrosion category (from ISO 9223) of the environment includes both mechanical and chemical stresses, and can affect both the thickness of the protective layer and the chemical compounds used. Limitations on environmental pollution laid down by local government, in particular solvent emissions, could limit the Volatile Organic Carbon (VOC) content present in some coatings.

One of the main considerations when choosing which coatings are the most beneficial will be cost. The cost (per litre) of the actual paint itself

was identified by the Ruukki team as negligible when compared to the costs incurred through the storage of the paint. Therefore the main factor affecting cost will be the lead time between coating and delivery. Also, the costs incurred by damage through transportation and the possibility for small-scale repair work should be considered.

The first step to be taken in the process entails researching what type of coatings are commonly used for steel piles, and what factors are considered when making this decision. The information can be gathered from coating suppliers; however, it would be beneficial to get some idea of what the customers of Ruukki commonly ask for from the sales department. From this information it should be possible to determine the environmental factors and corrosivity categories that need to be considered.

1.1 Surface Preparation

The surface areas of the sections of piles that are intended to be coated are cleaned in accordance with standard ISO 8501-1. These standards for surface cleaning outline the visual characteristics of the substrate as viewed by the naked eye. Once the substrate is cleaned, it is compared to reference pictures contained within the standards. The most commonly used in the paint systems for this project was Sa 2½, which is defined in ISO 8501-1 as having the following characteristics:

"Very thorough blast cleaning: Near white metal, 85% clean. The surface shall be free from visible oil, dirt and grease, from poorly adhering mill scale, rust, paint coatings and foreign matter. The metal has a greyish colour. Any traces of contamination shall be visible only as slight stains in the form of spots or stripes."

Some paints require a certain surface roughness in order to effectively adhere to the substrate. This is defined in ISO 8503-2 as surface profile, and describes the amplitude of the peaks and troughs (in microns) that are created during the surface preparation process. This surface profile is not indicative of the cleanliness of the surface, only the roughness.

There is no correlation between surface cleanliness and surface profile. The surface profile differs depending on the material used for blast cleaning, for example sand, ceramic, glass or metal, and the speed with which the media is shot. The surface profile can be measured and qualified by the Research and Development laboratory at Ruukki.

1.2 Spraying Method

Spraying paint onto any surface "is much faster than application by brush or roller" (Wicks et al 2007, 475). In industrial applications, spraying is the most common method of coating any surface; however, the benefits of spraying can most clearly be seen when coating irregularly shaped objects, such as the connecting parts of the steel piles used by Ruukki. The particu-

lar technique used for the paints described in this project is the airless spray gun.

Airless spraying techniques involve paint being "forced out of an orifice at high pressure, 5 to 35 MPa" (Wicks et al. 1997, 478). The paint appears to form a coating "sheet" to ensure a uniform and continuous coating layer. This uniformity is important as even the smallest discrepancy in the coating can lead to accelerated corrosion. Once any small-sized area of the substrate becomes exposed it will begin to corrode. This corrosion continues under the protective layer in the adjoining coated areas in all directions, even if the coating has not been damaged.

1.3 Lead Time

For the purposes of this project, the definition of lead time is from when the steel pile enters the painting facility, to when it is installed in the ground and all repair work is completed. The main factor in keeping lead time to a minimum is the drying time of the paint system for each pile. The lead time was singularly the most important factor affecting the decision of which paint systems to use.

The drying conditions described by the production team in the initial meeting were that of an ambient temperature (23 ^{o}C). However, they also expressed a desire to have systems that could dry rapidly in "winter conditions" (10 ^{o}C). The ambient temperature directly affects drying times, therefore a heating system or oven is more desirable. However, large ovens are expensive to install and run, and only heat the paint from the outside. One solution to this could be the use of heaters on the inside of the piles too. During discussion with Tikkurila it came to my attention the possibility of drying tubular steel piles from the inside. More specifically, closing off the ends and using an infra-red heater to heat the steel from the inside, in conjunction with an exterior heat source, drying whole of the paint layer more quickly. Infra-Red heaters could be one way to ensure that no damage is done to the coating, while reducing lead time and therefore overall costs.

1.4 Logistics

Due to the length of the steel piles in question, transport by boat is the normal way for the piles to travel. However, boats are prohibitively slow; therefore the maximum time to recoat for each system became a factor in the final decision.

1.5 On-Site Repair

In any construction project where the geology of the site is prohibitive, steel piles are driven deep into the ground to ensure the stability of the structure. Coastal construction work in particular relies on these deeply driven piles. "The piles can be installed using light equipment, which con-

serves the environment and reduces excavation need and costs considerably." (Rautaruukki, 2011)

It is almost impossible to drive piles deep into the ground without some form of damage. Damage can also occur during transportation of the piles; however, installation damage is the most common, and in some cases can be predictable. At the point where the pile-driving machinery grips the pile, the friction causes any coating to be stripped as seen in Figure 1. The black coating on the tubular steel pile has clearly been stripped to its substrate during installation. From the wide-angle picture (Figure 2) you can clearly see that this damage is common to all of the piles that have been installed in the same fashion.

Figure 1 Close-up of installation damage

Figure 2 Similar installation damage to all installed piles

Random occurrences of damage are also a factor as even the smallest discrepancy in the coating can cause acceleration in the corrosion of the substrate and therefore serious long term damage. Once any liquid and air mixture is exposed to one area of bare substrate causing accelerate corrosion, the surrounding areas become more susceptible. These small damages can occur at any time from the time of coating and even after installation is completed during the lifetime of the structure.

Figure 3 Minimal damage to a steel pile

The possibility for on-site repair of any damage to paintwork is therefore a limiting factor in the choice of the protective paint system. Any system that requires a high degree of roughness in order for the paint to adhere to the substrate was therefore discounted in the final selection to be contained within the sales tool.

1.6 Corrosion Mechanisms

There are three key areas to consider in steel pile corrosion, the tidal, splash and low-water zones, as illustrated in Figure 4. The low-water zone is in the submerged zone, just below lowest astronomical tide (LAT).

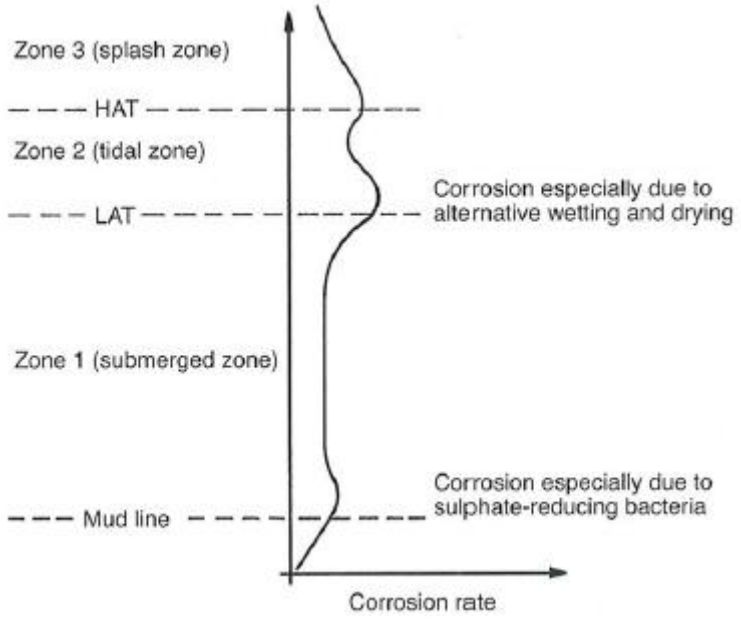

Figure 4 Tidal zones (Thoresen 2003, 401)

In these different areas, different mechanisms of corrosion are present at varying levels of aggression. These include mechanical, chemical, microbial and others such as Ultraviolet radiation. Therefore, "the corrosion performance of marine structures in these zones requires separate consideration." (Corus Group, 2005)

The most corrosion susceptible area of a steel pile is in the splash zone. This is the area at least 50 cm above the highest water level, or highest astronomical tide (HAT). The surface of the pile in the splash zone is cyclically changing in nature from wet to dry to wet. The corrosion mechanism is electro-chemical, i.e. "When two metals are in contact with water solution containing salts, an electric potential is formed between two different metals or the surfaces of the same metal with different surface conditions" (Livingsteel, 2010)

The low-water zone is the area just below the lowest astronomical tide (LAT); "It can only be observed over a few hours of each lunar cycle" (Johnson et al, 1997). Following a report made by three major steel sheet pile manufacturers in Europe in the early nineties, Accelerated low-water corrosion (ALWC) was found to be "microbially influenced due to the presence of a consortia of bacteria" (Moulin et al. 2001). Any coating of the steel, particularly when used in conjunction with cathodic protection is adequate to prevent microbial corrosion mechanisms.

The least affected area regarding steel pile corrosion is the tidal zone. This is the area that tends to accumulate barnacle and seaweed growth due to the changing atmospheric conditions of the tidal zone. These organisms can also act as a form of protection for the pile; "The marine growths can protect the piling by sheltering the steel from wave action between tides and by limiting the oxygen supply to the steel surface." (Corus Group, 2005)

2 AVAILABLE SYSTEMS

2.1 Painting Systems

There are many types of paint using very different complex mixtures of chemical substances. In this section the three types of paint that had clear and unique benefits for the purposes of this project are described.

Epoxy resins are commonly used for water-related applications. They are normally modified for a specific application or "formulated to maximise pot-life and minimise curing time", (Wicks et al 2007, 279) whilst adhering to the necessary standards associated with the end-use of the epoxy. General features of epoxy coatings include good adhesion properties, lack of ductility, protective qualities, and epoxies are normally inexpensive.

Polyester is one of the easier coating types to make with a low VOC content. A high solids content (and therefore low viscosity) is "required for the reduction of VOC emissions" (Wicks et al, 2007 205). General features of polyester coatings include Low VOC content, fast curing times and polyesters are also normally inexpensive.

Polyurethane based coatings are unique because they can be modified to be moisture-curable. These paints are typically one-pack systems that can cure in both humid and freezing conditions. The chemical reaction is complex, but put simply the "isocyanate resins react with the atmospheric water" (Wicks et al, 2007). General features of polyurethane coatings include flexible application conditions, heavy-duty applications and a resistance to UV-radiation.

2.2 Cathodic Protection

There are two types of Cathodic Protection (CP) that will be explained in this section: CP by sacrificial anode and impressed current CP. They work in different ways but largely have the same effect, with each having benefits on different scales of structure.

Cathodic protection does not work in all areas of a marine environment. It greatly reduces the corrosion of steel piles where the section is completely immersed at all times in water, or buried underground. Any section that is at times wet and at times dry is not affected positively by a cathodic protection system. Therefore cathodic protection should only be used in conjunction with a suitable coating, as illustrated in Figure 5:

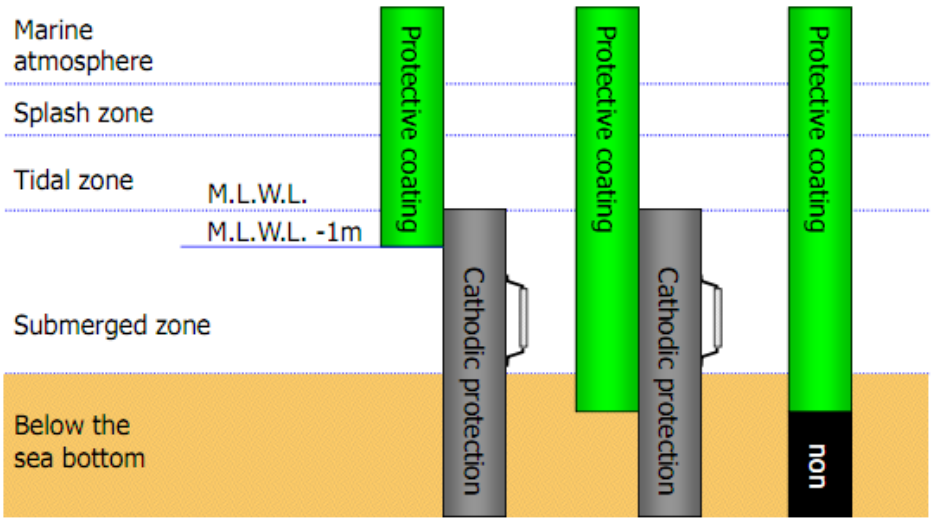

Figure 5 Different protection methods for port steel structures (Akira, n.d.)

The different properties of a coating may have different effects when combined with cathodic protection. For example metal content, if an epoxy contains aluminium; favourable effects on the associated cathodic protection can be expected. However, if the epoxy contains zinc phosphate it would be detrimental (Ferrari & Westing 1996, 14).

There are two types of CP system, the first being the Sacrificial Anode type. This CP system is a "passive" system and therefore requires no additional power sources and is very easy to maintain. "The anode is immersed in an electrolyte (the seawater) and electrically connected to the marine steel structure" (Thoresen 2003, 402). The corrosion occurs at the anode if it is a more reactive metal, and not the cathode (the piles). Merely replacing the anodes every 15-20 years is enough maintenance. While expensive, the anodes are generally easy to replace if the system is designed with maintenance as a consideration.

The second, more powerful CP system is the Impressed Current type. Sacrificial anodes cannot deliver enough current to provide complete protection for larger structures, so Impressed Current Cathodic Protection (ICCP) systems are used. (BAC Group 2009) This type of CP is an "active" system that requires large quantities of current. A rectifier converts the ac current to dc current (Thoresen 2003, 404). The anodes used in these systems are required to be inert.

2.3 Other systems

Plastic sheeting was discarded as a viable protection system for Ruukki's steel piles due to the "tongue and groove" style connectors between the sheet and tubular piles. This will cause the plastics sheets to be greatly damaged during installation and therefore reducing the effectiveness of the corrosive protection properties. Plastic would be greatly affected by possible non-repairable damaging factors such as installation (driving) and transportation.

Thermal sprayed aluminium (TSA) coatings protect steels against any typical water-based corrosion. Tidal and splash-zone corrosion being the most relevant applications in this report, but offshore structures and submersible components are also commonly coated using this method as a form of highly durable and long lasting protection. TSA provides a very good corrosion resistance at very low film thickness "It was reported that a 200 µm thickness TSA coating would provide a service life in excess of 30 years in a splash zone environment if optimised." (Shrestha & Sturgeon, 2005)

"Electric arc spraying and flame spraying are the most suitable methods for the corrosion protection of steel structures." (Doble & Pryde, 1997) However, due to these specialised techniques and the extra equipment that would be required to perform the coating, it was simply not a viable option for Ruukki at this time.

3 VIABILITY OF SYSTEMS

3.1 Required Coating Properties

All coatings are required to conform to the standard ISO 12944-5, and fit within the high corrosion resistance categories: C5-m, C5-I, Im2 or Im3. Together with this feature, good compatibility with cathodic protection systems was vital. Despite Ruukki not designing the CP system, almost all installations will include this type of additional protection system in some form. Finally, the ability to easily repair any damage to the coating due to transportation or installation was one aspect that some systems in particular failed to adhere to.

3.2 Desirable Coating Properties

In any project keeping costs under control is the most difficult, and yet most desirable factor. In pile coating, the most important factor with regard to minimising costs is shortening the length of the lead time. The easiest way to achieve this is by using one-coat systems instead of the more traditional three-coat systems. One alternative method for reducing drying time and therefore lead time is to include infra-red heaters on the inside of tubular piles in order to dry them from the internal surface together with traditional external heat sources.

From the sales point of view, the only way to effectively sell the coatings that Ruukki want to use is by being able to convince the customer that it is better in some way. For this, each system will require at least one unique selling point (USP). One of these points is a low VOC level. In the modern era, environmental concerns become more and more intrinsic to any industrial work. The VOC content of paint and painting facilities is already regulated, and the limits are lowered at regular intervals. Therefore systems that fall well within the acceptable range are far more desirable than those close to the acceptable limits.

High solids content is a term used for marketing purposes by paint suppliers, despite there being no clinical definition for what is considered to be "high-solid content". For heavy duty protective coatings it is generally assumed to be a minimum of 65 %. "A volume solids content of 80 % is considered as the general accepted standard for high solids coatings" (Keijman, n.d.). The use of high solids coatings has been primarily driven by environmental regulations as a way of reducing the solvent, or VOC content. Currently the most common paint types where high solids can be found are in epoxy and polyurethane based paints.

"Dry Film Thickness (DFT) is a critical measurement in the coating application process. It provides vital information as to the expected life of the substrate" (Elcometer, 2011). As well as helping to predict how the coating will perform, its aesthetics and compliance with many International Standards can be affected by DFT. Greater DFT is a good defence against accidental damage during transport. Usually however, a thicker paint layer is characterised by a longer lead time, which as mentioned before is the most important factor to consider reducing when considering cost effectiveness.

During one of the first meetings about this project, due to the unknown nature of Ruukki's painting facilities, winter application (painting in an ambient temperature below 10 ^{o}C) became another desirable quality of the prospective coating systems.

4 EXPERT OPINION

Many interviews were conducted in order to move from the theoretical case into what was really available on the market. After consulting with the specialists in the steel pile installation field at Ruukki, it became apparent that three Finnish companies and one German company had previously supplied paint for pile coatings. Due to the reputable nature of these companies together with an already established relationship (and therefore an existing supply chain) these were the preferred suppliers. They were therefore the first companies to be contacted for information regarding any way they could satisfy the requirements for this project.

The most common contact available to consult on this project in each possible supplying company was always a sales person; most of the information gathered was directly from the suppliers themselves, and from a "sales pitch" perspective. Therefore the objectivity of this information could be questioned and would need to be laboratory tested independently for verification.

4.1 Tikkurila Oyj

Two products were proposed by the team at Tikkurila, the data sheets are attached to this thesis as appendices: Temaline NL (Appendix 1) and Temabond WG 300 (Appendix 2). From the quantitative analysis in the next

chapter it is clear that Temaline NL is a better performing product in all of the categories. It was described by Tikkurila as a harder and therefore more corrosion resistant product. However, from the qualitative analysis it is shown the Temaline product to be unusable due to the nature of its bonding with the substrate. Temaline requires a greater roughness of the substrate in order to fulfil its cohesion bonding nature. Temabond is an adhesive coating which therefore sticks to even relatively smooth surfaces. Temabond is therefore recommended as the best coating for any works that require repairs to the coating to be made after transportation and installation. Temabond also performs well in corrosion resistance, but when compared to Temaline is inferior when looking at the two products from a quantitative perspective.

4.2 Nor-Maali Oy

The two products with the most promise proposed by Nor-Maali were the Baltoflake range and the Penguard Express system. The technical data sheets for Penguard Express NM and its associated topcoat Hartop AS can be found in Appendices 4 and 5 respectively. From both qualitative and quantitative viewpoints, the Baltoflake products are far superior. The Baltoflake coatings are "quick curing, high build, abrasion resistant styrene free glass flake reinforced polyester coatings" (Jotun, 2008) and includes three different paints. For the purposes of pile coating, the Baltoflake Ecolife (Appendix 3) product outperforms every other paint system researched in this entire project based on the quantitative analysis. The amazingly short drying time for a 1000 µm coat of 45 minutes is something that could not be ignored. This, coupled with the very low VOC content makes the Baltoflake Ecolife product an easy choice. However, the maximum time to recoat could become a problem. A maximum of only 14 days should be allowed between coats, leading to some concerns in particular with projects that are a greater distance to travel from the painting facility. Discussions should take place between Ruukki and Nor-Maali to determine whether small areas of damage can be "touched-up", as in the technical data sheet (see Appendix) the instructions are to contact them directly for discussions on a case-by-case basis. Factors affecting this decision would likely include the temperature and humidity of the location of the piles.

4.3 Teknos Oy

After exchanging e-mails with a representative of Teknos, The details of four paint systems were given, along with their associated high-solids variations. All of these systems were based on the traditional three-coat system, and despite some of them showing promise, they ultimately failed to fulfil the criteria required.

4.4 Steelpaint GmbH

Steelpaint is a company based in Germany that offers a truly unique coating system. Despite performing poorly in the quantitative analysis, the

Steelpaint system has undergone testing by Steelpaint and the company claims that the corrosion resistance is higher than any of the other systems discussed in this project. More impressively, their coatings can be applied in a variety of conditions including humidity, low temperatures, high temperatures and even onto a damp substrate. The Steelpaint system is designed to be applied on-site, and is the perfect system for the re-coating of piles after the factory coating has been corroded. The system has four coats, two primer coats of moisture-cure polyurethane zinc (Appendix 6), and two of a moisture-curing polyurethane topcoat (Appendix 7). The system is defined in Appendix 8. By using this system, it would be possible to eliminate the need to transport the piles to any painting facility. Despite the longer time required on-site for complete installation, the greatly reduced transportation times should more than compensate.

5 DISCUSSION

5.1 Quantitative Analysis

Table 1 shows the values for the key areas affecting the final decision on which coatings to select for the sales tool. The graph in Figure 3 shows a representation of the data in an easy to comprehend format.

Table 1 Key values for all considered paint systems

	Temaline	Temabond	Ecolife	Penguard	Steelpaint
Recommended DFT (µm)	500	300	1000	300	560
Lead time in factory conditions	8	10	0.45	9	32
VOC content (g/l)	110	300	20	311	308
Solids volume (%)	92	70	98	66	70

Figure 6 shows the data from the table in graphical form. The data has been scaled in order to highlight product performance. The scaling was based on 1000 units for the highest performing product in each category.

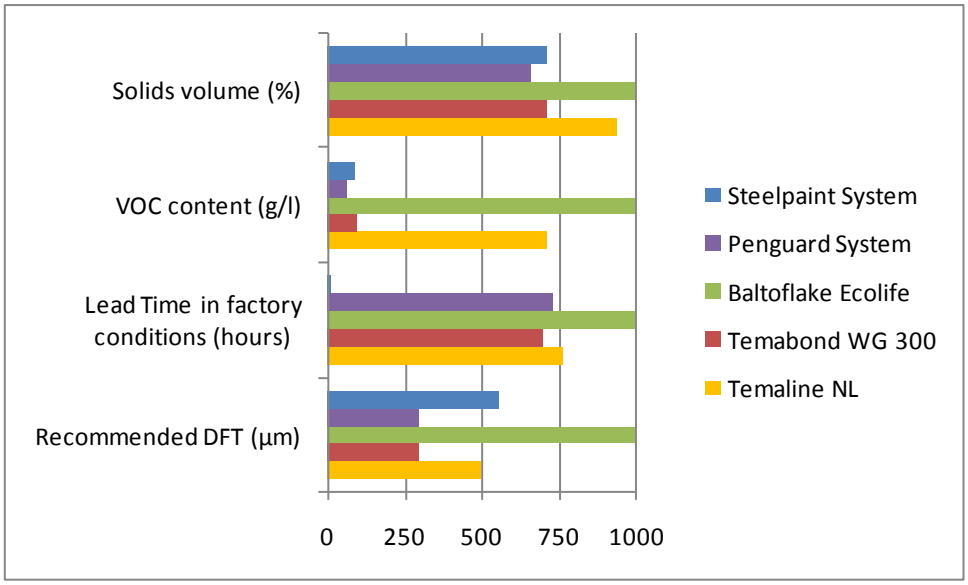

Figure 6 Graphical representation of data from table

From a basic analysis of the table, the benefits of the Baltoflake Ecolife product are clear to see; its statistics lead each category. The strengths of the Temaline NL system are also clear, however the limiting factor to this system becomes clear in the next section: qualitative analysis.

A comparison of the important quantitative data of the chosen new paint systems and some of the previously used systems can be found in Appendix 9. From this comparison it is clear that new systems outperform the previously used ones. Particular attention should be paid to the Baltoflake Ecolife product. The main factors to consider are drying time and VOC content (and therefore solids content).

5.2 Qualitative Analysis

Figure 7 is designed to effectively analyse the different important qualities, and limiting factors of each system. The qualitative benefits of the Steelpaint system become clear in this analysis. Also, the benefits of Temabond are clear, together with some reinforcement of the qualities of the Baltoflake product. The grey sections represent a particularly poor performance, and in the case of Temaline, a limiting factor that ultimately led to the system being discounted for use.

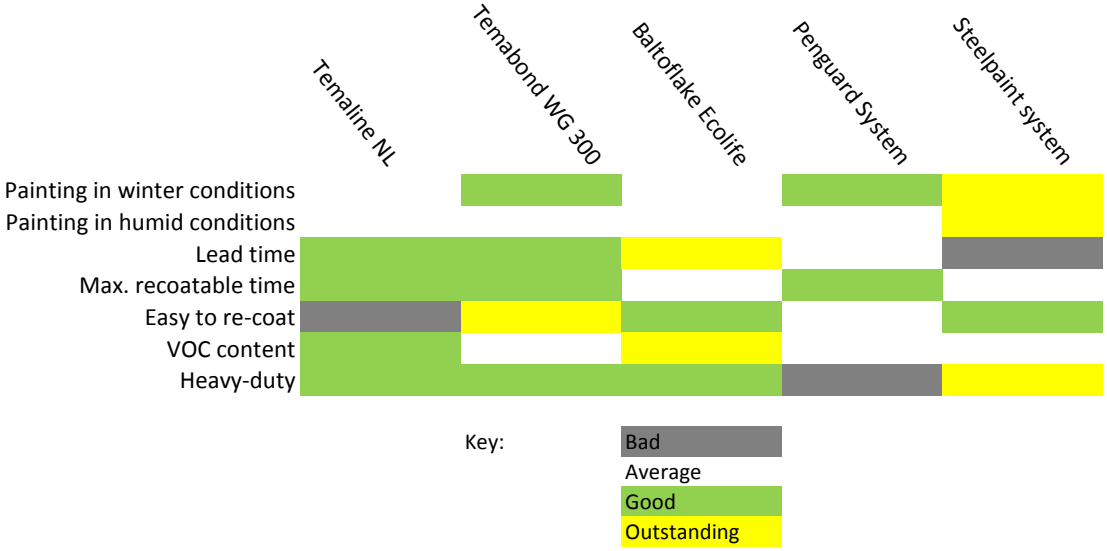

Figure 7 Qualitative analysis

6 CONCLUSION

The objective of this thesis project was to produce a sales tool for use by the sales team at Ruukki. The intended use is by the sales staff as a guide, not as a brochure or flyer to be distributed to customers, potential or otherwise. After meeting with Ruukki's sales team, suggestions were made regarding the format, structure and content of the sales tool. It was agreed that the key requirement needed from the sales tool is the ability to easily sell the pile coating to a customer as a better option than anything that they may propose themselves. Because of this, unique selling points (USP's) were required to be clearly defined. In addition, there needed to be clear differences between the proposed coatings to prevent any confusion as to which coating is suitable with regard to the various characteristics of an installation, such as environmental conditions or operational circumstances.

In order to keep the use of the sales tool quick and simple, it was structured in a basic segmented form. This could then be easily adjusted to suit whatever final decisions would be made with regard to paint supplier, paint type and aesthetics. The tool was divided into three segments, and the relevant sales information contained within the outer section. The use of simple colouring was to aid in the identification of the simple titles with the corresponding key information, yet not distracting from these unique selling points. The sales tool can be seen in Figure 8, and is designed to be produced at A5 size. These figures can also be found in Appendix 10 in actual size.

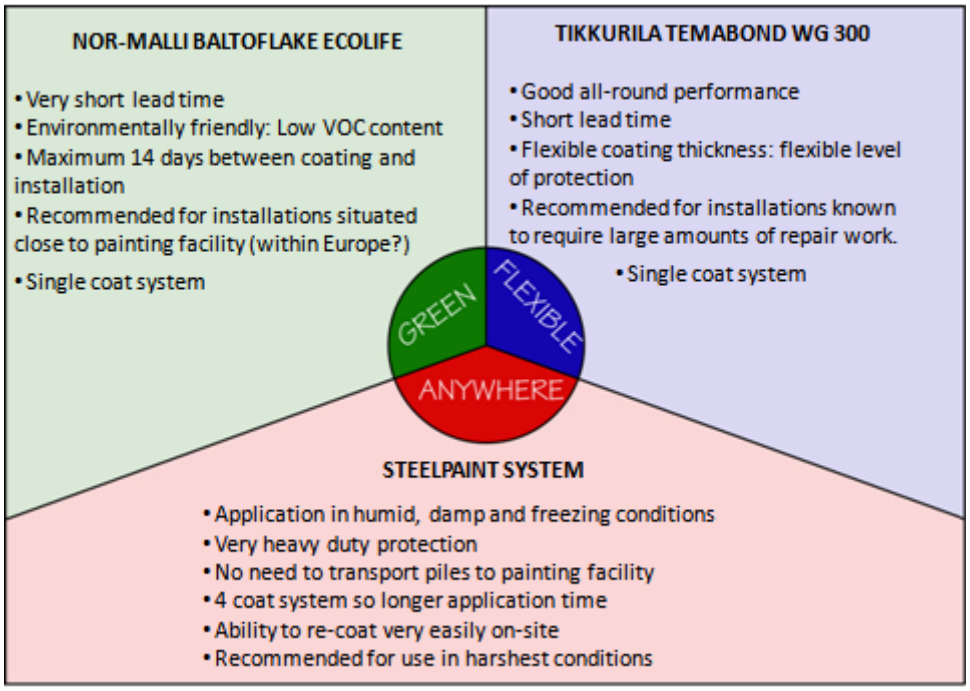

Figure 8 The proposed sales tool

On the reverse of the sales to it would be beneficial to have a simpler quick-reference guide like the one shown in Figure 9 below. One X denotes satisfactory performance in a category; two X's denotes a high performance.

	Nor-Maali Baltoflake Ecolife	Tikkurila Temabond WG 300	Steelpaint Stelpant system
Recommended Dry Film Thickness	1000 µm	300 µm	560 µm
Low lead time	**XX**	**X**	
Heavy duty	**X**	**X**	**XX**
Low VOC content	**XX**		
Easy to re-coat	**X**	**XX**	**X**
Painting in winter conditions		**X**	**XX**
Painting in humid conditions			**XX**
Maximum re-coatable period		**X**	

Figure 9 Quick reference guide

In order to objectively test the suitability of each paint type, independent laboratory testing is required. To confirm the logistical benefits of each system a time-axis flow chart comparison of the systems should be designed in order to identify the next limiting factor of lead time, if the drying time of the paint is reduced as significantly as expected. Packing of the

piles for transport is the most likely process stage to be this limiting factor. All of these ideas should then be incorporated (with the paint cost) into a cost analysis. Discussions with paint suppliers regarding cost per litre will need to take place in order for this to be possible. This cost analysis should show a reduced cost to Ruukki for the protective coating of the tubular steel piles that they supply.

SOURCES

Akira, Dr. Yoshikazu. Corrosion and Protection for Steel Pile. Accessed 24th August 2011. http://www.steelpile.com/images/bulltin_file/1259486544333369.pdf

BAC Group 2009. Products: Impressed Current CP. Accessed 8th September 2011. http://www.bacgroup.com/en/Products.aspx

Corus Group 2005. A Corrosion Protection Guide: For steel bearing piles in temperate climates. Scunthorpe: Corus Group

Doble O. & Pryde G. 1997. Use of Thermally Sprayed Aluminium in the Norwegian Offshore Industry. Protective Coatings Europe: Volume 2, Number 4.

Elcometer Ltd. 2011. Dry Film Thickness. Accessed 8th November 2011. http://www.elcometer.com/laboratory/lab-dry-film-thickness.html

Ferrari, G. & Westing, E. 1996. Development of low-alloy steels for marine applications: Corrosion and delamination mechanisms of painted low-alloy steel. Luxembourg: Office for Official Publications of the European Communities

Johnson et al. 1997. Low-water corrosion on steel piles in marine waters. Luxembourg: Office for Official Publications of the European Communities

Jotun 2008. Baltoflake Ecolife Technical Data Sheet. (See appendix)

Keijman, J.M. High Solids Coatings: Experience in Europe and USA. Ameron International, the Netherlands.

Livingsteel 2010. Corrosion: Introduction. Accessed 26th August 2011. http://www.livingsteel.org/corrosion

Moulin et al. 2001. Prevention of accelerated low-water corrosion on steel piling structures due to microbially influenced corrosion mechanisms. Luxembourg: Office for Official Publications of the European Communities

Rautaruukki, 2011. Website of Rautaruukki Oyj, page title: Steel piles. Accessed 30th August 2011. http://www.ruukki.com/Products-and-solutions/Infrastructure-solutions/Steel-piles

Shretha S. & Sturgeon A. 2005. Characteristics and electrochemical corrosion behaviour of thermal sprayed aluminium (TSA) coatings prepared by various wire thermal spray processes. Lisbon: EUROCORR

Thoresen, Carl A. 2003. Port Designer's Handbook (second edition). London: Thomas Telford.

Wicks Z P., Jones F N., Pappas S P. & Wicks D A. 2007. Organic Coatings (third edition). New Jersey: John Wiley & Sons

Appendix 1

TEMALINE NL TECHNICAL DATA SHEET

TIKKURILA

PRODUCT DATA SHEET 05.01.2007
REF. NO TCF 0002
1 (2)

TEMALINE NL

DESCRIPTION

A two component epoxy coating with a low solvent content.

PRODUCT FEATURES AND RECOMMENDED USES

- Excellent resistance to abrasion.
- Can be applied by standard airless spray equipment.
- Recommended for steel and concrete surfaces exposed to heavy abrasion and chemical stress.
- Resistance to chemicals is specified separately for each particular case.
- Withstands +150 °C dry heat and + 60 °C in immersion.
- Suitable for navigation markers, sluices, interiors of coal, wood chip and peat containers, and other surfaces exposed to heavy mechanical abrasion.

TECHNICAL DATA

Volume solids

92 ± 2 %. (ISO 3233)

Weight solids

95 ± 2 %.

Specific gravity

1.3 kg / l (mixed)

Mixing ratio and product codes

Base	2 parts by volume	110-series
Hardener	1 part by volume	008 6880

Pot life

45 min. (23 °C)

Recommended film thicknesses and theoretical coverage

Recommended film thicknesses		Theoretical coverage
dry	wet	
185 µm	200 µm	5.0 m^2/l
370 µm	400 µm	2.5 m^2/l

Practical coverage depends on the application method, painting conditions and the shape and roughness of the surface to be coated.

Drying times

DFT 250 µm	+ 10 °C	+ 23 °C	+ 35 °C
Dust dry, after	6 h	2 - 3 h	1½ h
Touch dry, after	20 h	12 h	5 h
Recoatable without sanding, after	8 - 72 h	4 - 48 h	2 - 24 h
Fully cured, after	14 d	7 d	3 d

Drying and recoating times are related to the film thickness, temperature, the relative humidity of the air and ventilation.

Finish

Glossy.

Colours

White, black, grey and shades of MKH. Other colours for request.

Tikkurila Oyj | P.O. Box 53 | Kuninkaalantie 1 | FI-01301 Vantaa | Tel. +358 (0)9 857 71 | Fax +358 (0)9 8577 6911
VAT FI01970674 | Business Identity Code 0197067-4 | Registered OfficeVantaa | www.tikkurila.com/industry

TEMALINE NL

APPLICATION DETAILS

Surface preparation	Oil, grease, salts and dirt are removed by appropriate means. (ISO 12944-4) Steel surfaces: Blast clean to grade Sa2½. (ISO 8501-1) If blast cleaning is not possible, phosphating is recommended for cold rolled steel to improve adhesion. Concrete surfaces: The surface must be dry and at least 4 weeks old. The relative humidity of the concrete should not exceed 97 %. Remove any splashes and unevennesses by grinding. Remove laitance and form oil from concrete castings by sanding or blast cleaning. Any cracks, crevices and voids must be repaired with a mixture of TEMALINE NL and fine dry quartz sand.
Primer	Steel surfaces: TEMALINE NL Concrete surfaces: Impregnation with 30 % thinned TEMALINE NL
Finish	Steel surfaces: 1 x TEMALINE NL Concrete surfaces: 1 - 2 x TEMALINE NL
Application conditions	All surfaces must be dry. The temperature of the ambient air, surface or paint should not fall below +10 °C during application and drying. Relative humidity should not exceed 80 %. The surface temperature of the steel should remain at least 3 °C above the dew point.
Mixing components	First mix the base and a necessary amount of thinner using mechanical stirring. Then add the pre-mixed hardener. The correct proportions of base and hardener must be mixed thoroughly before use. Use Temaspeed Squirrel Mixer for mixing.
Application	Application with a standard airless spray or a dual feed hot airless spray. Optimum spray temperature is around 40 - 50 °C. When necessary, heat the hoses. For repair painting of small areas the coating can be thinned 5 %. Airless spray nozzle tip 0.018" - 0.025". Spray angle shall be chosen according to the shape of the object. It is recommendable to use a reverse nozzle. Sharp edges, corners, weld seams and other areas difficult to paint should be painted by brush prior to spray application. For patching up small areas, the coating can be thinned abt. 5 %. **Note!** Pot life of the mixture is about 45 min. at + 23 °C and about 5 min. at + 40 °C. Avoid to let the mixture cure in hoses, pump or spray gun.
Thinner	Thinner 1031.
Cleaning of equipment	Thinner 1031.
VOC	The Volatile Organic Compounds amount is 90 ± 20 g/litre of paint mixture. VOC content of the paint mixture (thinned 30 % by volume) is 270 g/l.
HEALTH AND SAFETY	Containers are provided with safety labels, which should be observed. Further information about hazardous influences and protection are detailed in individual health and safety data sheets. A health and safety data sheet is available on request from Tikkurila Oyj.

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Appendix 2

TEMABOND WG 300 TECHNICAL DATA SHEET

TIKKURILA

PRODUCT DATA SHEET 18.02.2010
REF. NO TCF 0002
1 (2)

Temabond WG 300

DESCRIPTION

A two component, low temperature curing modified epoxy paint.

PRODUCT FEATURES AND RECOMMENDED USES

- Forms a tight coat with good chemical and abrasion resistance.
- Good adhesion also to wire-brushed steel.
- Especially used as a primer for steel surfaces difficult to clean in process and chemical industry and in water immersion, such as ship hulls and ballast tanks.
- Recommended for repairing of damages caused by transport or installation and for repainting and touch-up painting of earlier painted surfaces.
- Can also be applied on old alkyd paint surfaces.

TECHNICAL DATA

Volume solids

70 ± 2 %. (ISO 3233)

Weight solids

78 ± 2 %.

Specific gravity

1.3 kg / l (mixed)

Mixing ratio and product codes

Base	1 part by volume	176-series
Hardener	1 part by volume	008 7518

Pot life

1 hour (23 °C)

Recommended film thicknesses and theoretical coverage

Recommended film thicknesses		Theoretical coverage
dry	wet	
100 µm	145 µm	7.0 m^2/l
200 µm	290 µm	3.5 m^2/l

Practical coverage depends on the application method, painting conditions and the shape and roughness of the surface to be coated.

Drying times

DFT 150 µm	- 5 °C	0 °C	+ 5 °C	+ 10 °C	+ 23 °C
Dust dry, after	18 h	14 h	6½ h	3½ h	2½ h
Touch dry, after	48 h	36 h	17 h	9 h	5 h
Recoatable, after	48 h	36 h	17 h	9 h	5 h
Recoatable with epoxy, max. without sanding	2 months	2 months	2 months	2 months	2 months
Recoatable with polyurethane, after	-	-	14 d	14 d	14 d

Drying and recoating times are related to the film thickness, temperature, the relative humidity of the air and ventilation.

Finish

Semigloss.

Colours

TEMASPEED tinting.

Tikkurila Oyj | P.O. Box 53 | Kuninkaalantie 1 | FI-01301 Vantaa | Tel. +358 (0)9 857 71 | Fax +358 (0)9 8577 6911
VAT FI01970674 | Business Identity Code 0197067-4 | Registered OfficeVantaa | www.tikkurila.com

Temabond WG 300

APPLICATION DETAILS

Surface preparation	Oil, grease, salts and dirt are removed by appropriate means. (ISO 12944-4) Steel surfaces: Remove rust by tool cleaning to minimum St2 or blast clean to Sa2 or Sa2½ . Blast clean to grade Sa2½ for immersion. (ISO 8501-1). Earlier painted surfaces: Roughen old paint surfaces using e.g. abrasive wheel, sand paper or blast cleaning.
Primer	Temabond WG 300 and Temabond WG 200.
Finish	Temacoat GPL, Temacoat GPL-S MIO, Temacoat GPL-S Primer, Temacoat GS 50, Temacoat RM 40, Temadur, Temathane, Temacryl EA, Temabond WG 300 and Temabond ST 300.
Application conditions	All surfaces must be dry. The temperature of the ambient air and the surface should not fall below - 5ºC during application and drying.The temperature of the paint should be at least +15ºC. Relative humidity should not exceed 80%. The surface temperature of the steel should remain at least 3ºC above the dew point.
Mixing components	First stir base and hardener separately. The correct proportions of base and hardener must be mixed thoroughly before use. Use Temaspeed Squirrel Mixer for mixing.
Application	By airless spray or brush. If necessary, the paint can be thinned 0-10%. Airless spray nozzle tip 0.013"-0.019" and nozzle pressure 120-180 bar. Spray angle shall be chosen according to the shape of the object.
Thinner	Thinner 1031.
Cleaning of equipment	Thinner 1031.
VOC	The Volatile Organic Compounds amount is 300 g/litre of paint. VOC content of the paint mixture (thinned 10% by volume) is 350 g/l. Only for industrial and professional use.
HEALTH AND SAFETY	Containers are provided with safety labels, which should be observed. Further information about hazardous influences and protection are detailed in individual health and safety data sheets. A health and safety data sheet is available on request from Tikkurila Oyj.

Appendix 3

BALTOFLAKE ECOLIFE TECHNICAL DATA SHEET

Baltoflake Ecolife

Product description

Baltoflake Ecolife is a quick curing, high build, abrasion resistant styrene free glass flake reinforced polyester coating, that gives long time corrosion protection.

Recommended use

Steel structures in general and in particular items subject to extreme mechanical wear. May also be used for protection of aluminium and concrete (special designed systems). Baltoflake Ecolife can be applied as a non-skid coating system for walkways, escape routes and deck areas.

Film thickness and spreading rate

	Minimum	Maximum	Typical
Film thickness, dry (µm)	600	1500	1000
Film thickness, wet (µm)	610	1530	1020
Theoretical spreading rate (m^2/l)	1,63	0,65	0,98

Comments

The practical spreading rate may vary from the theoretical dependent upon film thickness and the ambient temperature, ventilation/wind during the application.

Physical properties

Colour	Limited number
Solids (vol %)*	98 ± 1
Flash point	53°C ± 2 (Setaflash)
VOC	20 gms/ltr UK-PG6/23(97). Appendix 3
Gloss	Semiflat
Gloss retention	Good
Water resistance	Excellent
Abrasion resistance	Excellent
Solvent resistance	Very good
Chemical resistance	Very good
Flexibility	Limited
Compatibility with cathodic protection	Very good

*Measured according to ISO 3233:1998 (E)

Surface preparation

All surfaces should be clean, dry and free from contamination. The surface should be assessed and treated in accordance with ISO 8504.

Bare steel
Blast cleaning to Sa 2½. (ISO 8501-1:2007). Roughness: using abrasives suitable to achieve a coarse surface of Grade Medium G (50-85µm, Ry5) (ISO 8503-2).

Other surfaces
The coating may be used on other substrates. Please contact your local Jotun office for more information.

Condition during application

The temperature of the substrate should be minimum 5°C and at least 3°C above the dew point of the air, temperature and relative humidity measured in the vicinity of the substrate. Good ventilation is usually required in confined areas to ensure proper drying. The coating should not be exposed to oil, chemicals or mechanical stress until fully cured.

Application methods

Spray	Preferably 2-comp. airless spray. Application with 1-comp. ordinary airless spray is also possible, provided that inhibitor is added.
Brush	Recommended for stripe coating and small areas, care must be taken to achieve the specified dry film thickness.

Application data

Mixing ratio (volume)	**2-comp. airless spray:** 1,25 vol.% Norpol Peroxide 13 at temperatures 10 - 35° C. 2,5 vol.% Norpol Peroxide 13 at temperatures 5 - 10° C. **1-comp. ordinary airless spray:** Addition of inhibitor and peroxide according to table on page 3. Norpol Peroxide 1 can be used instead of 13 at temperatures above 15° C.
Pot life (23°C)	15-20 minutes (Reduced at higher temperatures). After addition of inhibitor for 1-comp. ordinary airless spray: 35 minutes.
Thinner	Vinyl toluene. If needed max. 5% vinyltoluene.
Cleaner	Jotun Thinner No. 17 or Jotun Thinner No 27.
Guiding data airless spray	
Pressure at nozzle	15 - 25 MPa (150-250 kp/cm², 2100-4000 psi.)
Ratio/Capacity:	>45:1, min. 12 l per minute. Slow moving piston.
Nozzle tip	0,69 - 1.09 mm (0.027 - 0.043").
Spray angle	40-80°, best 60°.
Filter	To be removed.
Ratio/Capacity:	
Note	For further details please see separate "Working Manual". Approved alternatives to Norpol peroxide 13. can be used. Contact Jotun, Technical Service Department.

Drying time

Drying times are generally related to air circulation, temperature, film thickness and number of coats, and will be affected correspondingly. The figures given in the table are typical with:

* Good ventilation (Outdoor exposure or free circulation of air)
* Typical film thickness
* One coat on top of inert substrate

Using 2-comp. airless spray				
Substrate temperature	**5°C**	**10°C**	**23°C**	**40°C**
Surface dry	2.5 h	2.5 h	45 min	45 min
Through dry	2.5 h	2.5 h	45 min	45 min
Cured	3 d	2 d	12 h	4 h
Dry to recoat, minimum	2.5 h	2.5 h	45 min	45 min
Dry to recoat, maximum [1]	14 d	14 d	14 d	14 d
Using 1-comp. airless spray				
Substrate temperature		**10°C**	**23°C**	**40°C**
Surface dry		3 h	2 h	2 h
Through dry		3 h	2 h	2 h
Cured		3 d	2 d	1 d
Dry to recoat, minimum		3 h	2 h	2 h
Dry to recoat, maximum [1]		14 d	14 d	14 d

1. The surface should be free from chalking and contamination prior to application. If the maximum dry to recoat time is exceeded, please contact Jotun for advice.

The given data must be considered as guidelines only. The actual drying time/times before recoating may be shorter or longer, depending on film thickness, ventilation, humidity, underlying paint system, requirement for early handling and mechanical strength etc. A complete system can be described on a system sheet, where all parameters and special conditions could be included.

Typical paint system

Baltoflake Ecolife	**1 x 900 - 1100 µm**	**(Dry Film Thickness)**
or		
Baltoflake Ecolife	**2 x 600 - 750 µm**	**(Dry Film Thickness)**

Other systems may be specified, depending on area of use

MIXING RATIO BY USE OF 1-COMPONENT AIRLESS SPRAY

Temperature of steel and paint should not be lower than 10°C.

Steel and paint temp. °C	Addition of Norpol Inhibitor 9851		Addition of Norpol Peroxide 13	
	Volume percent	ml. into 16 litres of Baltoflake Ecolife	Volume percent	ml. into 16 litres of Baltoflake Ecolife
10 - 15	0.6	96	1.25	200
15 - 20	1.25	200	1.25	200
20 - 25	1.8	290	1.25	200
25 - 30	2.5	400	1.25	200
30 - 35	3.1	500	1.25	200

The temperature of the paint should never be more than 5°C higher than the steel temperature. The inhibitor should be mixed thoroughly with Baltoflake Ecolife before adding the required amount of Norpol Peroxide 13. Mechanical agitation for one minute or more is necessary to secure proper mixing of peroxide with the main component.

Note: Check temperature of pump during application. Friction in piston may cause increase in temperature. If this should happen, keep pump going to get heated Baltoflake Ecolife out as quickly as possible, and then wash the equipment.

Storage

The product must be stored below 25°C and in accordance with national regulations. Storage conditions are to keep the containers in a dry, cool, well ventilated space and away from source of heat and ignition. Containers must be kept tightly closed.
SHELF LIFE: 6 months, at 23°C, subject to re-inspection therafter. Shelf life very much depends on tempeature. Lower temperatures (if possible below freezing point) will lengthen the shelf life considerably, while high temperature may lead to gelling in the tin.

Handling

Handle Norpol Peroxide with care. Avoid that it comes in contact with combustible materiales. Accelerator and peroxide must never be mixed directly together.

Packing size

20 litre unit: 16 litres in a 20 litre container

Health and safety

Please observe the precautionary notices displayed on the container. Use under well ventilated conditions. Do not breathe or inhale mist. Avoid skin contact. Spillage on the skin should immediately be removed with suitable cleanser, soap and water. Eyes should be well flushed with water and medical attention sought immediately.

For detailed information on the health and safety hazards and precautions for use of this product, we refer to the Material Safety Data Sheet.

ISSUED 18 JANUARY 2008 BY JOTUN
THIS DATA SHEET SUPERSEDES THOSE PREVIOUSLY ISSUED

Appendix 4

PENGUARD EXPRESS NM TECHNICAL DATA SHEET

NOR MAALI JOTUN

Technical Data

Penguard Express NM

Product description

Penguard Express NM is a fast drying, high solids two-pack epoxy coating which may be applied in high film thickness and at lower temperatures.

Recommended use

As an anti corrosive primer and/or intermediate coating for corrosion protection of steel and other substrates in athmospheric exposure where fast dry-to-recoat and/or dry-to-handle times are desired. Can be used alone or in various systems of primers and topcoats.

Film thickness and spreading rate

	Minimum	Maximum	Typical
Film thickness, dry (µm)	75	200	125
Film thickness, wet (µm)	110	295	185
Theoretical spreading rate (m^2/l)	9,1	3,4	5,4

Physical properties

Colour	Grey, red and buff
Solids	68 ± 2 vol.%
Flash point	32°C ± 2
VOC	290 g/l (calculated value)
Gloss	Flat
Gloss retention	Fair
Water resistance	Very good
Abrasion resistance	Very good
Solvent resistance	Excellent
Chemical resistance	Excellent
Flexibility	Good

Surface preparation

All surfaces should be clean, dry and free from contamination. The surface should be assessed and treated in accordance with ISO 8504.

Bare steel
Cleanliness: Blast cleaning to Sa 2½ (ISO 8501-1:2007).
Roughness: using abrasives suitable to achieve grade Fine to Medium G (30-85 µm, Ry5) (ISO 8503-2).

Shopprimed steel
Clean, dry and undamaged approved shopprimer.

Coated surfaces
Clean, dry and undamaged compatible primer. Please contact Nor-Maali Oy for more information.

Other surfaces
The coating may be used on other substrates. Please contact Nor-Maali Oy for more information.

NORMAALI JOTUN

Condition during application

The temperature of the substrate should be minimum -5°C and at least 3°C above the dew point of the air, temperature and relative humidity measured in the vicinity of the substrate. Good ventilation is required in confined areas to ensure proper drying. The coating should not be exposed to oil, chemicals or mechanical stress until cured.

Application methods

Spray	Use airless spray
Brush	Recommended for stripe coating and small areas, care must be taken to achieve the specified dry film thickness.

Application data

Mixing ratio (volume)	4:1
Mixing	4 parts Comp. A (base) to be mixed thoroughly with 1 part Comp. B (curing agent) for 10 min prior to use.
Pot life (23°C)	2 hours. (Reduced at higher temp.)
Thinner/Cleaner	Jotun Thinner No. 17 (OH 17)
Guiding data airless spray	
Pressure at nozzle	15 MPa (150 kp/cm², 2100 psi)
Nozzle tip	0.018-0.027" (0.46 - 0.69 mm)
Spray angle	40 - 80°
Filter	Check to ensure that filters are clean.

Drying time

Drying times are generally related to air circulation, temperature, film thickness and number of coats, and will be affected correspondingly. The figures given in the table are typical with:

* Good ventilation (Outdoor exposure or free circulation of air)
* Typical film thickness
* One coat on top of inert substrate

Substrate temperature		-5°C	0°C	+5°C	+10°C	+23°C	+40°C
Surface dry		16 h	11 h	4 h	2 h	1 h	½ h
Through dry		38 h	24 h	10 h	6 h	3 h	2 h
Cured		-	21 d	13 d	8 d	4 d	3 d
Dry to recoat	min	24 h	14 h	8 h	4 h	2 h	1 h
	max[1]						

[1] Provided the surface is free from chalking and other contamination prior to application, there is normally no overcoating time limit. Best intercoat adhesion occurs, however, when the subsequent coat is applied before preceding coat has cured. If the coating has been exposed to direct sunlight for some time, special attention must be paid to surface cleaning and mattening/removal of the surface layer in order to obtain good adhesion.

The given data must be considered as guidelines only. The actual drying time/times before recoating may be shorter or longer, depending on film thickness, ventilation, humidity, underlying paint system, requirement for early handling and mechanical strength etc. A complete system can be described on a system sheet, where all parameters and special conditions could be included.

Typical paint system

Barrier	1 x 50 µm (Dry Film Thickness)
Penguard Express NM	**1 x 150 µm (Dry Film Thickness)**
Hardtop AS/Hardtop XP	1 x 50 µm (Dry Film Thickness)

or

Penguard Express NM	**2 x 125 µm (Dry Film Thickness)**
Hardtop AS/Hardtop XP	1 x 50 µm (Dry Film Thickness)

Other systems may be specified, depending on area of use.

NOR MAALI JOTUN

Storage

The product must be stored in accordance with national regulations. Storage conditions are to keep the containers in a dry, cool, well ventilated space and away from source of heat and ignition. Containers must be kept tightly closed.

Handling

Handle with care. Stir well before use.

Packing size

Comp A. 16 L
Comp B. 4 L

Health and safety

Please observe the precautionary notices displayed on the container. Use under well ventilated conditions. Do not breathe or inhale mist. Avoid skin contact. Spillage on the skin should immediately be removed with suitable cleanser, soap and water. Eyes should be well flushed with water and medical attention sought immediately. **For detailed information on the health and safety hazards and precautions for use of this product, we refer to the Material Safety Data Sheet.**

DISCLAIMER

The information in this data sheet is given to the best of our knowledge based on laboratory testing and practical experience. However, as the product is often used under conditions beyond our control, we cannot guarantee anything but the quality of the product itself. We reserve the right to change the given data without notice.

Data sheet 12/09

Sales and manufacture in Finland

NOR-MAALI Oy
Vanhatie 20 15240 Lahti
tel. +358-3-874 650

www.nor-maali.fi
firstname.familyname@nor-maali.fi
myynti@nor-maali.fi

Appendix 5

HARDTOP AS TECHNICAL DATA SHEET

Technical Data
Hardtop AS

JOTUN
Jotun Protects Property

Product description
Hardtop AS is a two-pack polyurethane topcoat with excellent gloss and colour retention. Hardtop AS bases are intermediates and need to be processed before use.

Recommended use
As topcoat over an epoxy/epoxy mastic system where a durable, high gloss finish is required in aggressive atmospheric exposure. Cures at low temperatures.

Film thickness and spreading rate

	Minimum	Maximum	Typical
Film thickness, dry (µm)	40	60	50
Film thickness, wet (µm)	80	120	100
Theoretical spreading rate (m^2/l)	12,5	8,3	10

Approvals
Australian APAS approved to specification 2911.

Physical properties

Colour	According to colour card and Multicolor tinting system (MCI)
Solids (vol %)*	50 ± 2
Flash point	26°C ± 2 (Setaflash)
VOC	415 gms/ltr UK-PG6/23(97). Appendix 3
Gloss	Glossy
Gloss retention	Excellent
Water resistance	Very good
Abrasion resistance	Very good
Solvent resistance	Very good
Chemical resistance	Very good
Flexibility	Very good

*Measured according to ISO 3233:1998 (E)

Surface preparation

All surfaces should be clean, dry and free from contamination. The surface should be assessed and treated in accordance with ISO 8504.

Coated surfaces
Clean, dry and undamaged compatible primer. Please contact your local Jotun office for more information.

Other surfaces
The coating may be used on other substrates. Please contact your local Jotun office for more information.

Condition during application

The temperature of the substrate should be minimum 0°C and at least 3°C above the dew point of the air, temperature and relative humidity measured in the vicinity of the substrate. Good ventilation is usually required in confined areas to ensure proper drying.

Application methods

Spray	Use airless spray
Brush	Recommended for stripe coating and small areas, care must be taken to achieve the specified dry film thickness.

Application data

Mixing ratio (volume)	4:1
Mixing	4 parts of Comp. A (base) to be mixed thoroughly with 1 part Hardtop AS/HB, Comp. B (curing agent).
Pot life (23°C)	4 hours (Reduced at higher temp.).
Thinner/Cleaner	Jotun Thinner No. 10
Guiding data airless spray	
Pressure at nozzle	15 MPa (150 kp/cm², 2100 psi).
Nozzle tip	0.33-0.46 mm (0.013-0.018").
Spray angle	40-80°
Filter	Check to ensure that filters are clean.

Drying time

Drying times are generally related to air circulation, temperature, film thickness and number of coats, and will be affected correspondingly. The figures given in the table are typical with:

* Good ventilation (Outdoor exposure or free circulation of air)
* Typical film thickness
* One coat on top of inert substrate

Substrate temperature	0°C	5°C	10°C	23°C	40°C
Surface dry	8 h	4 h	2 h	1 h	0,5 h
Through dry	40 h	30 h	16 h	8 h	4 h
Cured	20 d	15 d	10 d	5 d	2 d
Dry to recoat, minimum	24 h	18 h	10 h	5 h	2,5 h
Dry to recoat, maximum [1]					

1. The surface must be free from any chalking or any other contamination and if necessary, sufficiently roughened prior to application.
2. Early exposure to condensation (high humidity, low temperature) may cause colour and/or gloss variations.

The given data must be considered as guidelines only. The actual drying time/times before recoating may be shorter or longer, depending on film thickness, ventilation, humidity, underlying paint system, requirement for early handling and mechanical strength etc. A complete system can be described on a system sheet, where all parameters and special conditions could be included.

Typical paint system

Jotamastic 87	2 x 150 µm	(Dry Film Thickness)
Hardtop AS	**1 x 50 µm**	**(Dry Film Thickness)**

Note: To obtain full coverage an extra coat may be necessary, especially for signal colours in red, orange and yellow.
Other systems may be specified, depending on area of use

Storage

The product must be stored in accordance with national regulations. Storage conditions are to keep the containers in a dry, cool, well ventilated space and away from source of heat and ignition. Containers must be kept tightly closed.

Handling

Handle with care. Stir well before use.

Packing size

20 litre unit: 16 litres Comp. A in a 20 litre container and 4 litres Hardtop AS/HB Comp. B in a 5 litre container.
or
5 litre unit: 4 litres Comp. A in a 5 litre container and 1 litre Hardtop AS/HB Comp. B in a 1 litre container.

Health and safety

Please observe the precautionary notices displayed on the container. Use under well ventilated conditions. Do not breathe or inhale mist. Avoid skin contact. Spillage on the skin should immediately be removed with suitable cleanser, soap and water. Eyes should be well flushed with water and medical attention sought immediately.

For detailed information on the health and safety hazards and precautions for use of this product, we refer to the Material Safety Data Sheet.

DISCLAIMER

The information in this data sheet is given to the best of our knowledge based on laboratory testing and practical experience. However, as the product can be used under conditions beyond our control, we can only guarantee the quality of the product itself. We also reserve the right to change the given data without notice. Minor product variations may be implemented in order to comply with local requirements.
If there is any inconsistency in the text the English (UK) version will prevail.

Jotun is a World Wide company with factories, sales offices and stocks in more than 50 countries. For your nearest local Jotun address please contact the nearest regional office or visit our website at www.jotun.com

ISSUED 26 NOVEMBER 2010 BY JOTUN
THIS DATA SHEET SUPERSEDES THOSE PREVIOUSLY ISSUED

Appendix 6

STELPANT-PU-ZINC TECHNICAL DATA SHEET

STELPANT-PU-ZINC

STEELPAINT

Type:
1-Component Moisture Cure Polyurethane (MCPU) zinc coat.

Basic properties:
Designed as a primer for different, highly sophisticated coating systems. Extreme adhesion and durability under extreme atmospheric and climatic conditions, can for example be used in the seawater tidal zone containing high concentrations of salt.

Extraordinary properties:
This 1-component product can be applied under extreme humid conditions (30% to 98% rel. air humidity), even on slightly damp surfaces and temperatures below 0°C (max - 10°C). Fast curing properties even below the freezing point and in extreme humid conditions. Therefore it is possible to work with STELPANT-PU-ZINC the entire year even outside.

Principal use:
Suitable in the maritime, railway and industrial area, e.g. steel plates, bridges, steel constructions (halls, hangars, and workshops), piping, off-shore platforms, locks, pressure vessels for gas and liquid, containers, storage tanks, pipelines, sewage treatment plants, heavy welded structures, steel foundations for industry and nuclear power plant components.

Special purpose:
Suitable as a primer and maintenance primer and as one-layer coat for export purposes and as protection for temporary constructions.

Resistance:
Offers extreme protection against severe weather conditions and chemical fumes and vapours and is extremely resistant against fresh- and seawater and short term effects of acids, alkalis and greases.

Surface preparation:
Surfaces have to be free of salts, greases, oils, dissolving agents, and all other possible contaminations. Due to the moisture curing properties of the STELPANT-PU-ZINC primer, water-jetting and high-pressure water-jetting are especially suitable as cleaning methods for the steel surfaces that have to be coated. Extreme adhesion on sandblasted (Sa 2 ½) or manually prepared (St 2) steel-surfaces. Good corrosion protection even on slightly corroded steel surfaces (rust film).

Application methods:*
- Airless spray
- Brush and roller
- Conventional spray

Application conditions:
Surface temperature from -10°C to +50°C. Can be applied in a humidity range from 30% to 98% rel. air humidity.

Primers and intermediate coats:
STELPANT-PU-ZINC is especially suited as a primer in combination with additional STELPANT 1C-MCPU products (for additional information please contact our Steelpaint-representative).

* additional information on the following pages

STELPANT-PU-ZINC

STEELPAINT

Technical product information:

Binder	Moisture Cure Polyurethan
Colour	Grey*
Thinner	STELPANT-PU-THINNER
Volume solids (DIN 53219)	approx. 71,0 %
Theoretical coverage	approx. 80 µm DFT = 2,85 m² / kg
Density	approx. 3,1 kilo / l (3,1 g / cm³)
Temperature resistance	up to +160°C, temporarily up to +200°C
Chemical resistance	*for additional information please contact our Steelpaint- representative*
Pack size	3 liter und 10 liter units
Storage properties	12 months in unopened original packing and stored under dry conditions at a temperature between +5°C and +30°C

* due to the production process little deviations are possible

Terms of application:

- Airless spray — supplied viscosity
  tip-size 0,43 - 0,48 mm (= 0,017 - 0,019 inch)
  pressure 180 - 240 bar (= 180 - 245atm / 2600 - 3450 psi)

- Conventional spray — viscosity 25 - 30 sek. bei 4mm (DIN 53211)
  tip-size 1,5 -1,8 mm
  pressure 3 - 4 bar (= 3 - 4 atm / 40 – 60 psi)

- Brush and roller: — supplied viscosity

Thinning is normally not required. Longer storage may lead to an increase in viscosity, in that case add STELPANT-PU-THINNER.

STELPANT-PU-ZINC

Curing and overcoating times:

At 20 °C ambient temperature and 60 % rel. air humidity:

Curing time	Dust-dry: ≤ 20 minutes Tack-free: ≤ 1 hour
Overcoating time	possible after approx. 4 hours.

The shown numbers in the table are general advising values. Curing and overcoating times depend on ambient temperature, rel. air humidity, dry film thickness and the used application method.

This product information sheet contains advising technical information only. The mentioned purpose use, application methods, and material consumption data are general. Binding values and advises are project related.

Steelpaint GmbH, P.O. Box 231, D-97305 Kitzingen, Germany
Tel: +49-(0)9321-37040, Fax: +49-(0)9321-370440, E-Mail: mail@steelpaint.com
www.steelpaint.com

Appendix 7

STELPANT-PU-COMBINATION TECHNICAL DATA SHEET

STELPANT-PU-COMBINATION 100

Type:
1-Component Moisture Cure Polyurethane (MCPU) Coating

Basic properties:
Designed as an intermediate or top coat for different, highly sophisticated coating systems. Extreme adhesion and durability under extreme atmospheric and climatic conditions, can for example be used in the seawater tidal zone containing high concentrations of salt.

Extraordinary properties:
This 1-component product can be applied under extreme humid conditions (30% to 98% rel. air humidity), even on slightly damp surfaces and temperatures below 0°C (max - 10°C). Fast curing properties even below the freezing point and in extreme humid conditions. Therefore it is possible to work with STELPANT-PU-COMBINATION 100 the entire year even outside.

The first coat of STELPANT-PU-COMBINATION 100 should cure for at least 12 hours before over coating. A faster over coating interval is possible under special circumstances (wet-on-wet)**. The second coat can also be applied after several days or even weeks.

Principal use:
Suitable as exterior and interior coat in the maritime and industrial area, e.g. port facilities, offshore constructions, ships, pipelines, power plants, bridges, sewage treatment plants, piping and storage tanks.

Special purpose:
Especially suitable as an intermediate and top coat system under extreme environmental conditions in the maritime and offshore area.

Resistance:
Protects against severe weather conditions and is resistant against fresh- and seawater, oils, greases and short term effects of acids, alkalis, thinners, salts and salt solutions.

Surface preparation:
Surfaces have to be free of salts, greases, oils, dissolving agents, and all other possible contaminations.

Application methods:*
- Airless spray
- Brush and roller
- Conventional spray

Application conditions:
Surface temperature from -10°C to +50°C. Can be applied in a humidity range from 30% to 98% rel. air humidity.

Primers and intermediate coats:
STELPANT-PU-COMBINATION 100 is especially suited as an intermediate and/or topcoat in combination with additional STELPANT 1C-MCPU products (for additional information please contact our Steelpaint-representative).

* additional information on the following pages
** for additional information please contact our Steelpaint- representative

Steelpaint GmbH, P.O. Box 231, D-97305 Kitzingen, Germany

STELPANT-PU-COMBINATION 100

STEELPAINT

Technical product information:

Binder	Moisture Cure Polyurethan
Colour	Black, red-brown, special colours*
Thinner	STELPANT-PU-THINNER
Volume solids (DIN 53219)	approx. 70,0 % (depends on colour)
Theoretical coverage	approx. 150 µm DFT = 4,7 m² / l = 3,4 m² / kg
Density	1,4 kilo / l (1,4 g / cm³)
Temperature resistance	up to +120°C
Chemical resistance	*for additional information please contact our Steelpaint- representative*
Pack size	3 liter und 10 liter units
Storage properties	12 months in unopened original packing and stored under dry conditions at a temperature between +5°C and +30°C

* due to the production process little deviations are possible

Terms of Application:

- Airless spray: supplied viscosity
  tip-size 0,5 - 0,7 mm (=0,019 - 0,027 inch)
  pressure 180 - 240 bar (= 180 - 245atm / 2600 - 3450 psi)

- Conventional spray: viscosity 25 - 35 sec. at 4mm (DIN 53211)
  tip-size 1,5 -1,8 mm
  pressure 3 - 4 bar (= 3 - 4 atm / 40 – 60 psi)

- Brush and roller: supplied viscosity

Thinning is normally not required. Longer storage may lead to an increase in viscosity, in that case add STELPANT-PU-THINNER.

Appendix 8

STEELPAINT SYSTEM DETAILS

Maintenance – Steel Surfaces in Submerged or Splash Water Zone as Sea and Port Structures, Sheet Piling, Cooling water Pipes etc.

	Product name	Product Type	Color	DFT µ	VS %	TSR m^2/ltr
F/C or T/U	Stelpant-PU-Zinc	1-pack moisture cured PU Zinc	Grey	80	71	8.9
F/C or T/U	Stelpant-PU-Zinc	1-pack moisture cured PU Zinc	Grey	80	71	8.9
F/C	Stelpant-PU-Combination 100	1-pack moisture cured PU Combination	Black	200	70	3.5
F/C	Stelpant-PU-Combination 100	1-pack moisture cured PU Combination	Black	200	70	3.5
				560		

The VOC levels are:

Stelpant PU Zinc - 261,628 g/l

Conbination 100 - 320,215 g/l

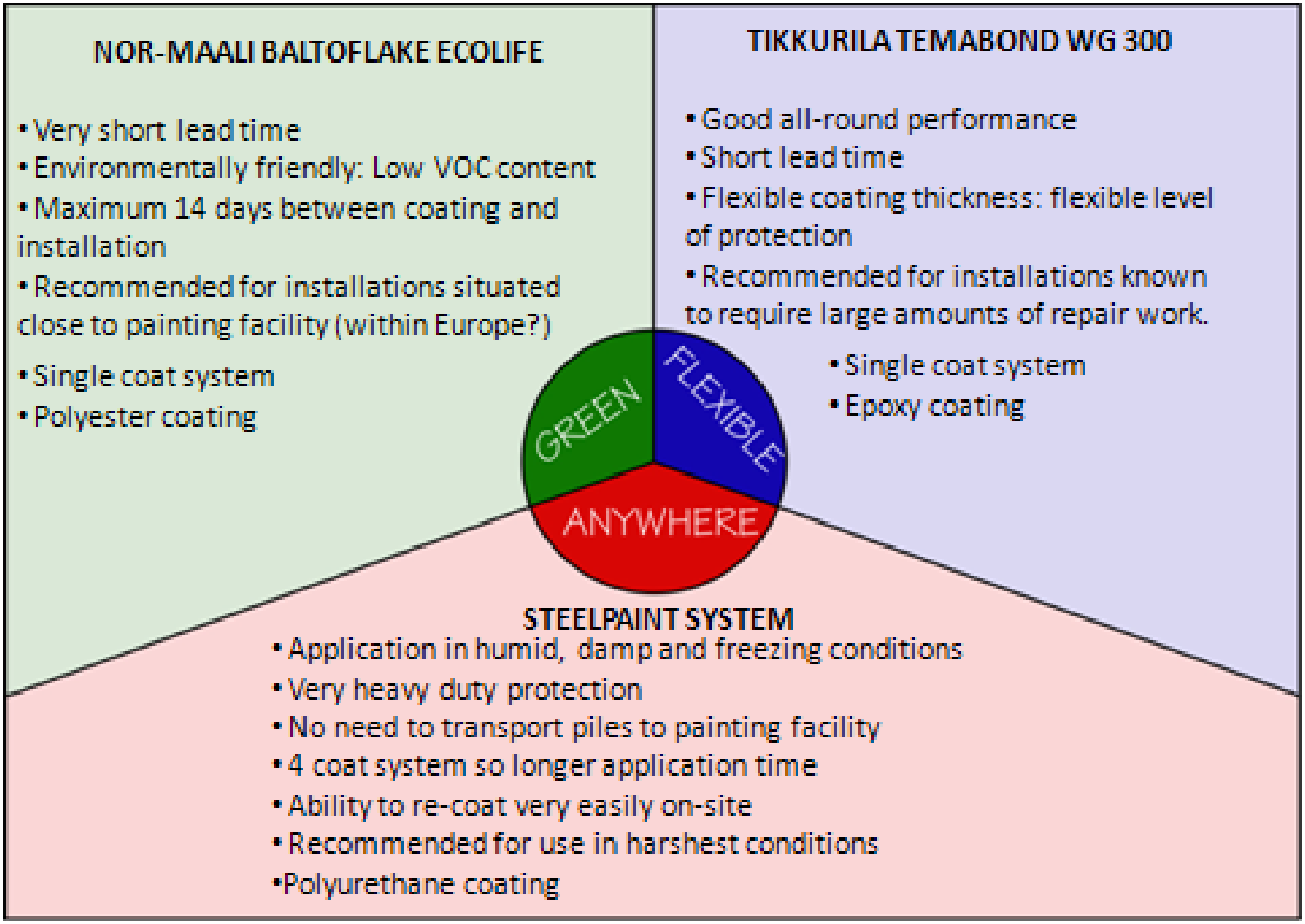
Appendix 9

COMPARISON BETWEEN SELECTED OLD AND NEW PAINT SYSTEMS

Coating system	**thickness of coating film**	**dry content**	**10°**	**23°**	**40°**	**VOC g/l**
SikaCor Zinc R	50	67 %	5	2½	1½	<500
SikaCor SW500	500	100 %	28	12	3	
Sigmacover 256	50	63 %	4	3	2	338
Sigmacover 456	50	65 %	4	3	2	347
Sigmadur 550	50	55 %	8	6	3	450
Temacoat RM40	125	65 %	10	4	2	310
Temacoat RM40	125	65 %	10	4	2	310
Temacoat RM40	125	65 %	10	4	2	310
Temabond WG 300	150	70%	9	5		300
Temabond WG 300	150	70%	9	5		300
Stelpant-PU-Zinc	80	71%	>4	4	<4	260
Stelpant-PU-Zinc	80	71%	>4	4	<4	260
Stelpant-PU-Combination 100	200	70%	>12	12	<12	320
Stelpant-PU-Combination 100	200	70%	>12	12	<12	320
Baltoflake Ecolife	1000	98%	2.5	0.45	0.45	20

Appendix 10

	Nor-Maali Baltoflake Ecolife	Tikkurila Temabond WG 300	Steelpaint Stelpant system
Recommended Dry Film Thickness	1000 µm	300 µm	560 µm
Low lead time	XX	X	
Heavy duty	X	X	XX
Low VOC content	XX		
Easy to re-coat	X	XX	X
Painting in winter conditions		X	XX
Painting in humid conditions			XX
Maximum re-coatable period		X	


NOR-MAALI BALTOFLAKE ECOLIFE
• Very short lead time
• Environmentally friendly: Low VOC content
• Maximum 14 days between coating and installation
• Recommended for installations situated close to painting facility (within Europe?)
• Single coat system
• Polyester coating
TIKKURILA TEMABOND WG 300
• Good all-round performance
• Short lead time
• Flexible coating thickness: flexible level of protection
• Recommended for installations known to require large amounts of repair work.
• Single coat system
• Epoxy coating
GREEN
FLEXIBLE
ANYWHERE
STEELPAINT SYSTEM
• Application in humid, damp and freezing conditions
• Very heavy duty protection
• No need to transport piles to painting facility
• 4 coat system so longer application time
• Ability to re-coat very easily on-site
• Recommended for use in harshest conditions
•Polyurethane coating